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# Engineering Research Report

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# U. H. F. medium distance tropospheric propagation measurements over the English Channel

## No. 1972/6

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

# U.H.F. MEDIUM DISTANCE TROPOSPHERIC PROPAGATION MEASUREMENTS OVER THE ENGLISH CHANNEL

Research Department Report No. 1972/6
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Research Department Report No. **1972/6**

# U.H.F. MEDIUM DISTANCE TROPOSPHERIC PROPAGATION MEASUREMENTS OVER THE ENGLISH CHANNEL

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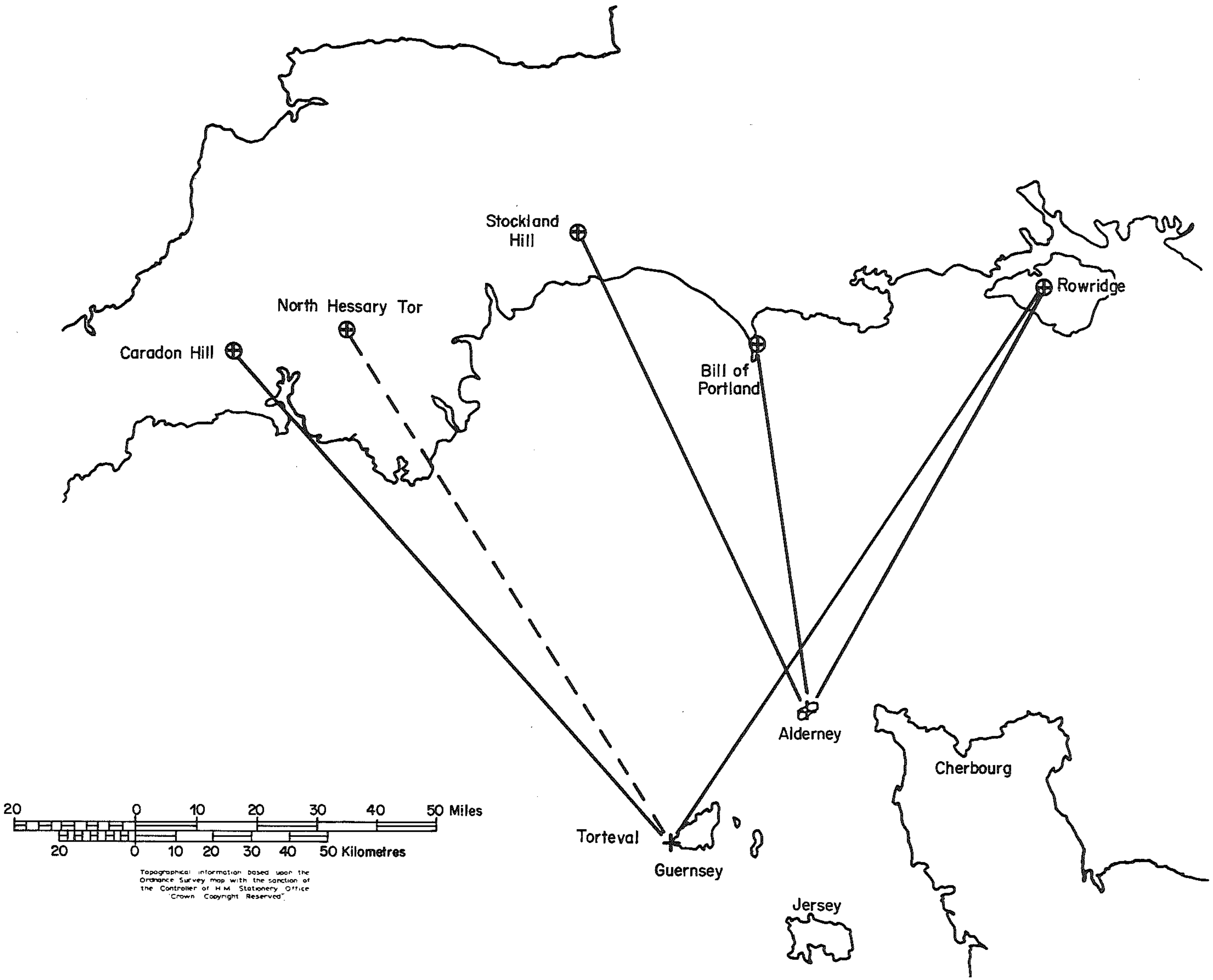

Topographical information based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office "Crown Copyright Reserved".

*Fig. 1 - Geographical location of transmitting and receiving sites*

⊕ Transmitting Sites + Receiving Sites

March 1972

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# U.H.F. MEDIUM DISTANCE TROPOSPHERIC PROPAGATION MEASUREMENTS OVER THE ENGLISH CHANNEL

## Summary

*In extending the u.h.f. television network, consideration must be given to the most suitable means of providing a programme feed to the Channel Islands. Any direct re-broadcast link from the mainland of the United Kingdom must be at least 95 km in length and will thus be subject to a considerable degree of fading. This report summarises the statistical results of a number of long-term propagation tests carried out over various representative transmission paths in the area. This information is required to determine not only the most suitable link path, but also the degree of complexity of the equipment required at the receiving terminal.*

## 1. Introduction

Over the period from 1962 to 1971 the BBC have carried out a series of long-term propagation measurements across the English Channel at frequencies in Bands IV and V. These measurements, made at receiving sites on the Channel Islands of Alderney and Guernsey had the general objective of providing statistical data regarding propagation over medium distance sea paths, and more specifically, of providing information necessary to engineer a 625-line programme feed to the proposed Jersey and Guernsey u.h.f. transmitters. Further work is still required to determine the most suitable means of providing programme feed and this report is intended primarily as a summary of the statistical data obtained. The measured results are compared with predictions obtained by various alternative methods, such comparisons being of importance in indicating any systematic errors in existing prediction methods over this type of path.

## 2. Transmitting and receiving site details

The first transmission path investigated was that from the BBC transmitting site at North Hessary Tor (Devon) to the BBC receiving station at Torteval (Guernsey). This path is that currently used for providing the 405-line programme feed to the transmitter at Les Platons (Jersey), onward transmission from Torteval to Les Platons being by means of an s.h.f. link. Since the range of the receiving equipment was insufficient to record abnormally high field strengths, and the transmitting site was more than 40 km from the coast, these results are detailed separately in the Appendix rather than in the main text of the report.

The geographical locations of this and other transmission paths are as shown in Fig. 1, the receiving site in each case being either Torteval or the Post Office receiving station on Alderney. All but one of the transmitting sites (Portland) are existing BBC or ITA television transmitters. The sound channel transmissions of the existing Band IV broadcasts from Rowridge (Isle of Wight) and Caradon Hill (Cornwall) were used for the measurements involving these stations. The ITA transmitting station at Stockland Hill, was not yet operational on u.h.f. at the time of the measurements. Transmissions from this site and from the site at Portland (H.M. Prison, The Verne) were provided by means of low power c.w. test transmitters.

Details of transmitting and receiving sites are shown in Tables 1 and 2. Simultaneous measurements of the Rowridge and Portland transmissions at Alderney were made at two receiving aerial heights to enable the advantage obtainable from space diversity reception to be assessed. All transmissions were horizontally polarised, except for that from Portland which was horizontally polarised for the first half of the period of the tests and vertically polarised thereafter.

*TABLE 1*

*Transmitting Site Details*

| Transmitter | Transmission Freq. (MHz) | Site Height a.m.s.l. (m) | Aerial Height a.m.s.l. (m) | Latitude | Longitude | Transmitter e.r.p. towards receiving site(s) dB rel. to 1 kW |
|---|---|---|---|---|---|---|
| Rowridge | 501·25 | 137 | 280 | 50°40′33″N | 1°22′02″W | +9 |
| Caradon Hill | 533·25 | 370 | 602 | 50°30′36″N | 4°26′10″W | +19 |
| Stockland Hill | 756 | 229 | 461 | 50°48′23″N | 3°06′15″W | −17·5 |
| Portland Bill | 666 | 148 | 156 | 50°33′48″N | 2°26′04″W | −17 |

## 3. Results

### 3.1. Analysis

The received field strengths were recorded both on pen recorders and on punched tape, the latter form of record being obtained by sampling at half-minute intervals. Recordings of Rowridge and Caradon Hill were, of course, confined to broadcast transmission hours whereas those of Stockland Hill and Portland were continuous.

### 3.2. Variation of field strength with time

The records were analysed to determine the length of time during which the signals exceeded various levels of field strength. These time durations, expressed as percentages of the overall valid recording time, were then plotted against field strength in decibels relative to 1 $\mu$V/m (dB ($\mu$V/m)) for an e.r.p. of 1 kW. The results of this analysis are shown in Fig. 2.

Values of field strength exceeded for specified time percentages, derived from the distribution curves of Fig. 2 are given in Table 3. Also given in this Table are the relevant path lengths, free space field strengths, and periods of duration of the various measurements. The following points should be noted:—

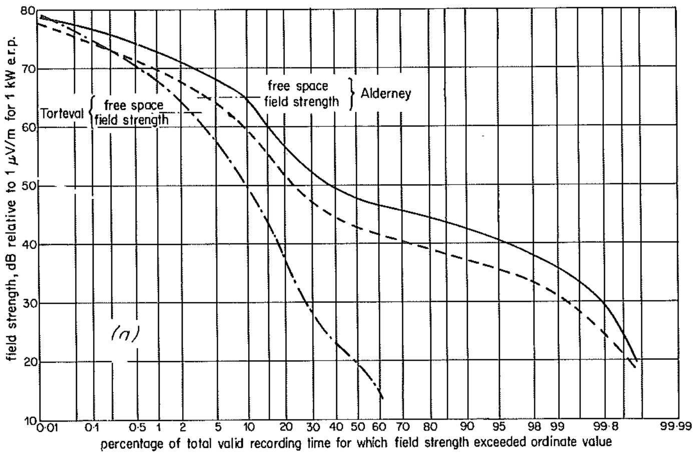
(i) Measurements over the Portland to Alderney path extended over a total period of ten months, in which horizontally polarised transmissions were used for the first five months, and vertically polarised transmissions thereafter. Comparison of the two sets of results (Fig. 2(*c*)) shows no evidence of differences attributable to polarisation and the figures given in Table 2 are derived by combining the two individual sets of results. Simultaneous measurements with receiving aerials at 90 m and 69 m a.m.s.l. were made for the first three months of these tests, the measurements at the lower height being discontinued thereafter. Since the field strength/time percentage distribution for this initial period is not representative of that for the whole duration of measurements over this path the field strength distribution for the lower receiving aerial is not shown in Fig. 2(*c*) but is discussed in a later section.

(ii) Valid measurements over the Stockland Hill to Alderney path were limited to a four-month period from August to November 1970. This would normally be considered to be too short a period to provide reliable statistical data. However, the field strength distribution obtained from reception of Caradon Hill at Torteval over this same period of time was very similar to that obtained for the full two-year measurement period over this path, (Fig. 2(*b*)). It therefore seems reasonable to assume that the Stockland Hill to Alderney results are also representative of those obtainable over a more extensive period.

*TABLE 2*

*Receiving Site Details*

| Receiving Site | Site Height a.m.s.l. (m) | Receiving Aerial Height(s) a.m.s.l. (m) | Latitude | Longitude |
|---|---|---|---|---|
| Alderney (P.O. Link Site) | 60 | 90 (upper)<br>69 (lower) | 49°43′11″N | 2°11′22″W |
| Torteval (Guernsey) | 68 | 80 | 49°25′54″N | 2°40′08″W |

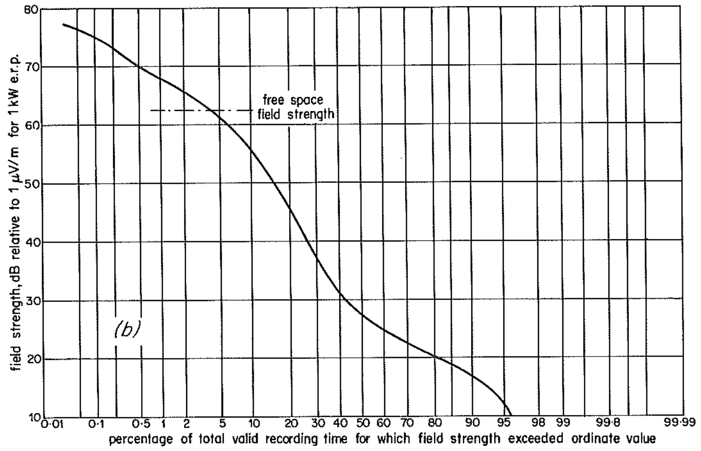


Reception of transmission from Rowridge on 501·25 MHz

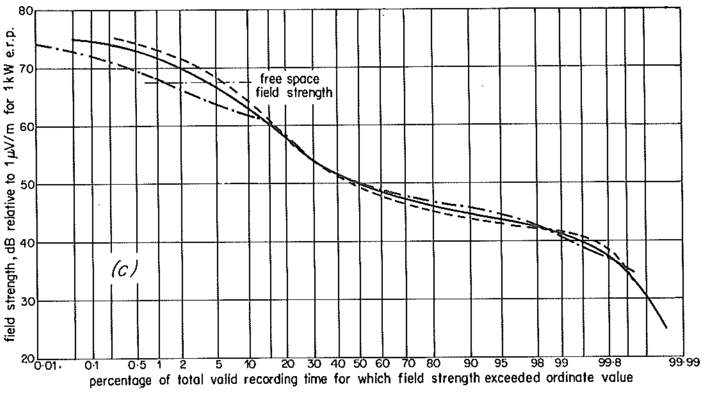
▬ Receiving site Alderney, receiving aerial 90 m a.m.s.l.

– – – Receiving site Alderney, receiving aerial 69 m a.m.s.l.

–·– Receiving site Torteval, receiving aerial 80 m a.m.s.l.



Reception of transmission from Caradon Hill at Torteval
Transmission frequency 533·25 MHz, receiving aerial 80 m a.m.s.l.

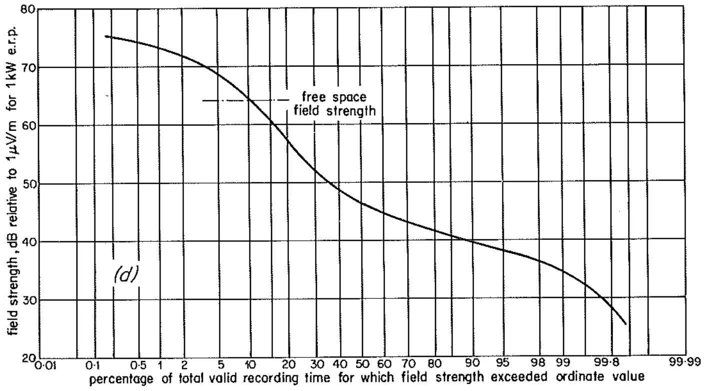


Reception of transmission from Portland at Alderney
Transmission frequency 666 MHz, receiving aerial 90 m a.m.s.l.

▬ Combined results over total period of recording

– – – Results for period with vertically polarised transmissions

–·– Results for period with horizontally polarised transmissions



Reception of transmission from Stockland Hill at Alderney
Transmission frequency 756 MHz, receiving aerial 90 m a.m.s.l.

*Fig. 2 - Variation of field strength with time*

## *TABLE 3*

*Tabulated Results of Measurement over the Various Paths*

| Transmission Path | Path Length (km) | Free Space Field Strength dB (μV/m) for 1 kW e.r.p. | Field Strength exceeded for specified time percentage dB (μV/m) for 1 kW e.r.p. | | | | | | | Duration of measurements |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0·1% | 1% | 5% | 10% | 50% | 90% | 99% | |
| Rowridge to Alderney (1) | 121 | 65 | 76·5 | 73·0 | 68·0 | 64·5 | 47·5 | 42·5 | 25·5 | Feb. 1967 to Feb. 1969 |
| Rowridge to Alderney (2) | 121 | 65 | 74·0 | 69·5 | 64·0 | 59·5 | 43·0 | 37·0 | 21·0 | |
| Rowridge to Torteval | 167 | 62·5 | 74·5 | 68·0 | 57·0 | 49·0 | 19·5 | | | Feb. 1967 to Sept. 1970 |
| Caradon Hill to Torteval | 174 | 62 | 75·0 | 68·0 | 61·0 | 55·0 | 27·0 | 16·5 | | July 1969 to July 1971 |
| Stockland Hill to Alderney | 137 | 64 | 75·0 | 73·5 | 68·5 | 64·5 | 46·5 | 39·5 | 24·5 | August 1970 to Nov. 1970 |
| Portland to Alderney | 95 | 67·5 | 74·0 | 71·0 | 66·0 | 62·5 | 49·5 | 44·5 | 34·5 | Feb. 1970 to Nov. 1970 |

(1) Receiving aerial 90 m a.m.s.l.
(2) Receiving aerial at 69 m a.m.s.l.

## 4. Monthly field strength variations

Field strength values exceeded for specified time-percentages in each month are shown in Fig. 3(*a*) – 3(*d*) for which at least two years of measurement data are available. The figures show the great extent of the variation from month to month and emphasise the need to carry out such measurements over prolonged periods to provide reliable statistical data, particularly for low-time percentages.

There is evidence of a tendency for signal levels to be higher during the summer months than during the winter. This trend which can be readily explained by reference to the radio-meteorology of the lower troposphere above the sea surface[1] has already been noted in the Reports on previous BBC measurements over sea and mixed land/sea paths.

It is also of interest to note that the overall variation of the median (50%) value of field strength exceeds 30 dB for both the two series of results obtained from reception at Torteval (Figs. 3(*c*) and 3(*d*)), implying that during some summer months 'anomalous' propagation conditions of ducting and super-refraction may persist for more than half the time. This range of variation of the monthly median field strength is significantly greater than that observed in previous u.h.f. propagation experiments[2,3] traversing the North Sea and involving a rather longer transmission path (198 km) associated with somewhat lower terminal heights (transmitting aerial 60 m a.m.s.l., receiving aerial 24 m a.m.s.l.). The monthly variation of the median in these earlier experiments did not exceed 20 dB. It would therefore seem that the variation of monthly median field strength does not increase continuously as the path length increases, but rather passes through a maximum probably associated with the distance between horizons from transmitting and receiving terminals.

## 5. Comparison with predicted field strength values

### 5.1. General

For frequency planning purposes it is of considerable interest to compare the experimental results to those obtainable by means of various established field strength prediction methods. Such methods are described in:–

(1) The CCIR Second Atlas of Ground Wave Propagation Curves
(2) The Japanese Ministry of Postal Services Atlas of Radio Wave Propagation Curves
(3) The Method of CCIR Recommendation 370-1 and Report 239.2
(4) The Method of CCIR Report 425.

These comparisons will be discussed individually.

### 5.2. Comparison of measured results to those of CCIR[4] and Japanese Atlases[5]

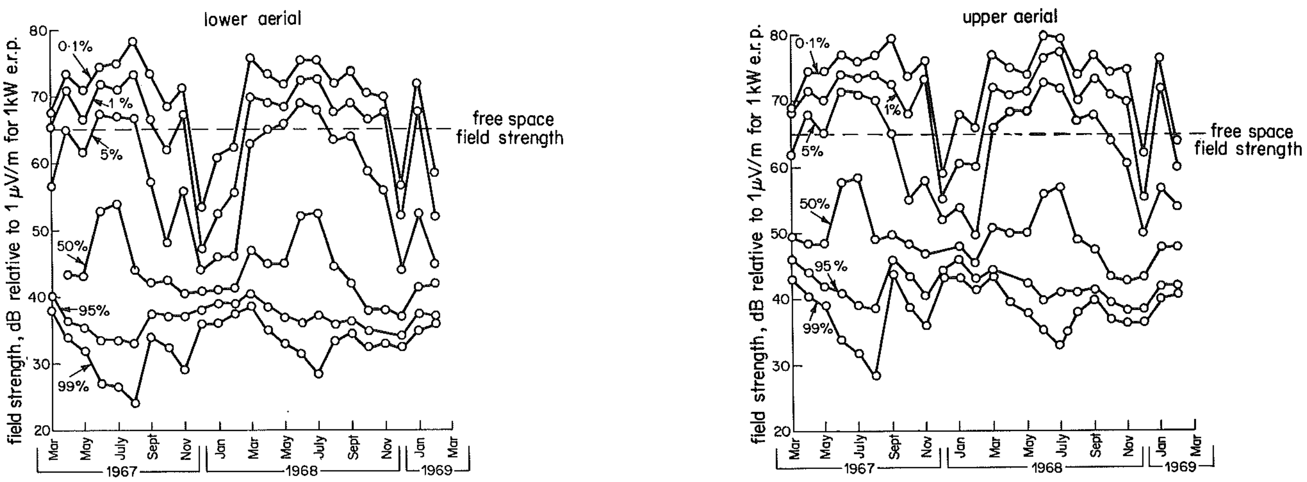
Both of these Atlases of Propagation Curves are derived in an essentially similar manner from the mathematical treatment by Van de Pol and Bremmer for propagation through a standard atmosphere over a smooth spherical earth. This standard atmosphere is one having a refractive index lapse rate such as to provide an effective earth radius = $^4/_3$ x the true value. For this reason the curves are only suitable for prediction of the field strength occurring under normal conditions, i.e. the 50% time values.

Considerable interpolation errors are possible in reading predicted field strength values from either Atlas, and it is probable that such errors are somewhat greater than any differences between the Atlases. The predicted values given in Table 4 represent the average of the individual interpolation values derived from the two Atlases, the values having been confirmed by calculation using the simplified mathematical treatment due to Vogler.[6]

*TABLE 4*

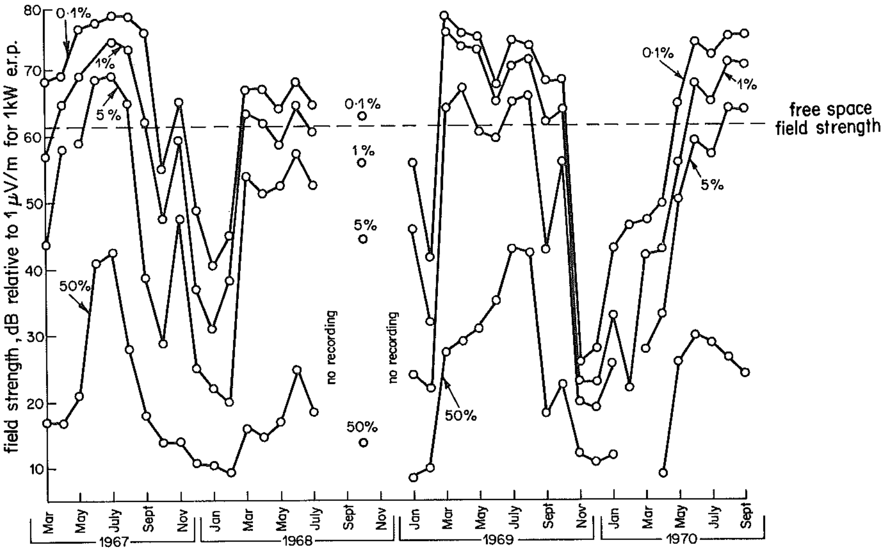
*Comparison between Median (50% time) Measured Field Strength and Values Derived from Atlases of Propagation Curves*

| Path | d (km) | $h_t$ (m) a.m.s.l. | $h_r$ (m) a.m.s.l. | Measured Field Strength [dB(μV/m) for 1 kW e.r.p.] | Predicted Field Strength [dB(μV/m) for 1 kW e.r.p.] | Distance between horizons assuming 4/3 earth radius (km) |
|---|---|---|---|---|---|---|
| Rowridge to Alderney | 121 | 280 | 90 | 47·5 | 42·0 | 14 |
| Rowridge to Alderney | 121 | 280 | 69 | 43·0 | 38·5 | 19 |
| Rowridge to Torteval | 167 | 280 | 80 | 19·5 | 5·0 | 61 |
| Caradon Hill to Torteval | 174 | 602 | 80 | 27·0 | 22·5 | 37 |
| Stockland Hill to Alderney | 137 | 461 | 90 | 46·5 | 44 | 10 |
| Portland to Alderney | 95 | 156 | 90 | 49·5 | 49·5 | 5 |
| Portland to Alderney | 95 | 156 | 69 | 45·5 | 45·5 | 10 |

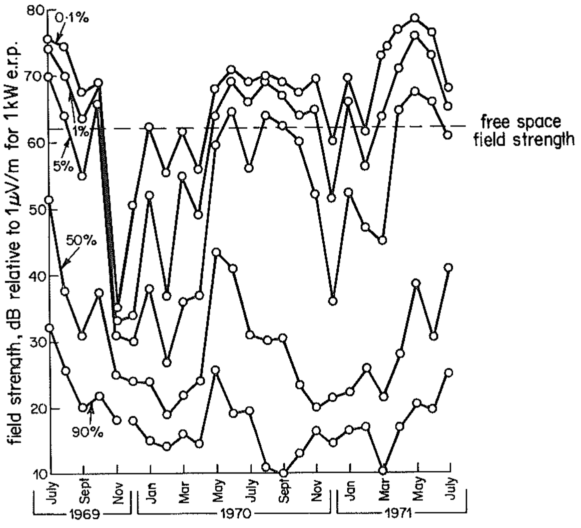


(*a*) Reception of Rowridge at Alderney — receiving aerial 90 m a.m.s.l.

(*b*) Reception of Rowridge at Alderney — receiving aerial 69 m a.m.s.l.



(*c*) Reception of Rowridge at Torteval



(*d*) Reception of Caradon Hill at Torteval

*Fig. 3 - Field strengths exceeded in each month for selected time percentages*

*TABLE 5*

*Comparison between Measured Field Strengths and Predictions using Method of CCIR Rec. 370-1*

| Path | Actual Path Length (km) | Effective* Path Length (km) | Predicted field strength for specified time percentage† dB(μV/m) for 1 kW e.r.p. | | | | Ratio Pred.: Meas. field strengths (dB) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1% | 5% | 10% | 50% | 1% | 5% | 10% | 50% |
| Rowridge to Alderney receiving aerial 90 m a.m.s.l. | 121 | 95 | 75 | 64 | 59 | 39 | +2 | −4 | −5·5 | −8·5 |
| Rowridge to Alderney receiving aerial 69 m a.m.s.l. | 121 | 100 | 74·5 | 63 | 57 | 35 | +5 | −1 | −2·5 | −8 |
| Rowridge to Torteval | 167 | 143 | 71 | 54 | 46 | 19 | +3 | −3 | −3 | −0·5 |
| Caradon Hill to Torteval | 174 | 150 | 72 | 58 | 55 | 23 | +4 | −3 | 0 | −4 |
| Stockland Hill to Alderney | 137 | 111 | 75 | 64 | 59 | 35 | +1·5 | −4·5 | −5·5 | −11·5 |
| Portland to Alderney receiving aerial 90 m a.m.s.l. | 95 | 69 | 75 | 66 | 61 | 46 | +4 | 0 | −1·5 | −3·5 |
| Portland to Alderney receiving aerial 69 m a.m.s.l. | 95 | 74 | 74·5 | 65 | 60 | 44 | No results** | | | −1 |

* Equivalent to actual path length reduced by 4·1 ($\sqrt{h_r} - \sqrt{10}$) km.

† Corrected for open coastal receiving location (+ 7 dB)

** Measurements not sufficiently extensive to provide reliable comparisons under abnormal propagation conditions.

*TABLE 6*

*Comparison between Measurements and Predictions using Method A of CCIR Report 425*

| Path | Receiving Aerial height (m) a.m.s.l. | Predicted Field Strength exceeded for specified time percentage dB(μV/m) for 1 kW e.r.p. | | | Ratio, Predicted Field Strength : Measured field strength (dB) | | |
|---|---|---|---|---|---|---|---|
| | | 1% | 5% | 50% | 1% | 5% | 50% |
| Rowridge to Alderney | 90 | 65 | 65 | 56 | −8 | −3 | +8·5 |
| Rowridge to Alderney | 69 | 65 | 65 | 56 | −4·5 | +1 | +7 |
| Rowridge to Torteval | 80 | 62·5 | 62·5 | 16 | −5·5 | +5·5 | −3·5 |
| Caradon Hill to Torteval | 80 | 62 | 62 | 37 | −6 | −1 | +10 |
| Stockland Hill to Alderney | 90 | 64 | 64 | 57 | −9·5 | −4·5 | +10·5 |
| Portland to Alderney | 90 | 67·5 | 67·5 | 60 | −3·5 | +1·5 | +10·5 |

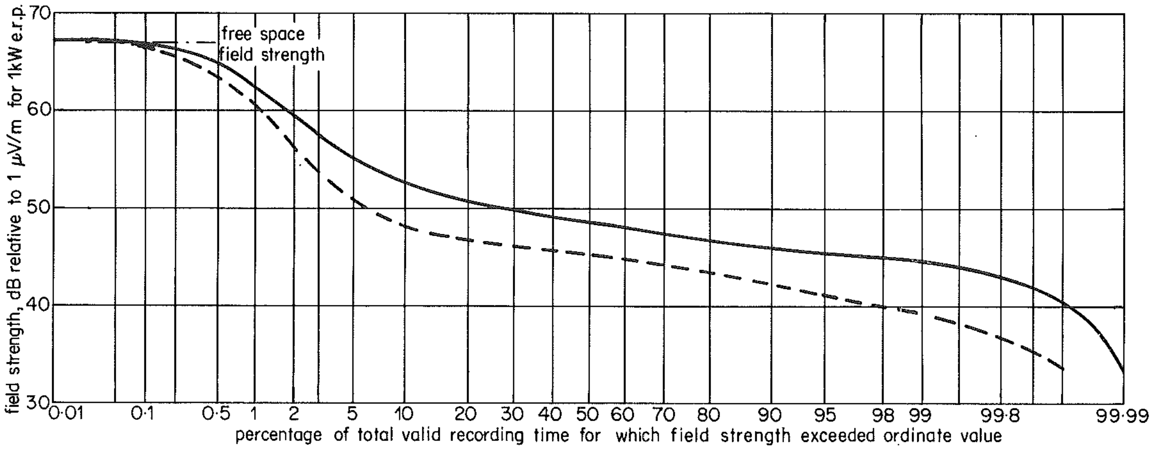


*Fig. 4 - Variation of field strength with time*

Reception of transmission from Portland at Alderney on 666 MHz

——— Receiving aerial 90 m a.m.s.l. — — — Receiving aerial 69 m a.m.s.l.

From Table 4 it can be seen that measured and predicted field strengths are identical for the shortest transmission path (Portland to Alderney). The remainder of the measured results exceed the predicted values by an amount which tends to increase with greater transhorizon distance. Except in the case of the longest path this discrepancy does not exceed 6 dB and may be attributed to the increase in monthly median field strength in the summer months noted in the previous section. In other words the annual median refractive index lapse rate over the English Channel is probably somewhat greater than the value required to give an effective earth curvature factor of $^4/_3$.

The path from Caradon Hill to Torteval has a much greater distance between horizons than any of the other paths and shows a much greater discrepancy (16·5 dB) between measured and predicted field strengths. It must however be remembered that the spherical diffraction calculation method takes no account of the scatter mode of propagation which is of primary importance under normal propagation conditions at distances well beyond the radio horizon. Thus, for example, earlier results[2,3] obtained over a 200 km path traversing the North Sea and having a distance of nearly 150 km between horizons gave measured median field strengths more than 60 dB greater than the values predicted by the theoretical diffraction calculation.

The results in Table 4 thus serve to indicate the range of usefulness of these Atlases in predicting median field strengths.

### 5.3. Comparison of measurements and CCIR prediction method of Recommendation 370-1

CCIR Recommendation 370-1[7] provides a series of semi-empirical curves indicating the field strength exceeded for specific percentages of the time at v.h.f. and u.h.f. for both overland and oversea propagation paths. Whilst all the paths detailed in Table 3 contain some overland portion, this is in all cases (except possibly Caradon Hill to Torteval) sufficiently small for the paths to be considered as all oversea. The CCIR curves refer, however, to reception at 50% of receiving locations and it is therefore necessary to apply corrections to the predicted values to relate them to reception conditions pertaining to the measurements.

These corrections are in two parts:—

(i) A reduction in effective path length to compensate for the non-typical location of the receiving site. The height gain characteristics of the curves of Rec. 370-1 were normalised for a transmitting aerial height of 300 m and a receiving aerial height of 10 m by assuming the field strength to be a function only of the distance between horizons.[8] Thus to obtain the field strength at distance x km from a transmitter for receiving aerial heights of $h_t$ and $h_r$ the curves should be read for a distance of $(x+70-4{\cdot}1\sqrt{h})$* km where $\sqrt{h} = \sqrt{h_t} + \sqrt{h_r}\sqrt{10}$.

Since the curves themselves indicate the allowance for $h_t$ it is necessary only to modify the effective path length to allow for the amount by which $h_r$ differs from 10 m.

(ii) The curves of Rec. 370-1 relate to reception in a coastal town rather than at an open coastal site directly overlooking the sea. A correction of −7 dB[9] has been allowed for this purpose.

The comparisons between measured and predicted field strengths are shown in Table 5. It may be seen that predicted field strengths tend to be higher than the measured values for 1% time and lower for other time percentages. Nevertheless the discrepancy exceeds 6 dB only for the 50% time values of the transmission paths from Rowridge and Stockland Hill terminating in Alderney.

### 5.4. Comparisons of measurements and CCIR prediction method of Report 425

For reasons which have been discussed elsewhere[10] the BBC no longer uses the prediction method of CCIR Recommendation 370-1 and Report 239-2 for frequency planning in the u.h.f. broadcast band. The method currently employed, which is suitable for use by computer, was developed within the BBC Research Department[11] and comprises Method A of CCIR Report 425.[12] Table 6 shows the comparison between measurements and predicted field strengths using this prediction method. It may be noted that all paths lie within the distance range for which this prediction method assumes both 1% and 5% time values to be equal to the free-space field strength. Since for the majority of the paths the field strength exceeded for 1% of the time is considerably above the free-space value it follows that predicted values are inevitably too low for this time percentage. Conversely with one exception the predicted values exceed the measured field strengths by between 7 and 10·5 dB at the 50% time level.

## 6. Receiving aerial height gain and vertical space diversity

As previously discussed, field strength measurements of the transmissions from Rowridge and Portland were made at two receiving aerial heights on Alderney. Comparative field strength time percentage distribution for reception of Rowridge at the two heights were shown in Fig. 2(*a*) and for reception of the Portland transmission* are shown in Fig. 4.

As was indicated in Table 4 the effective** receiving aerial height gain for 50% time in both instances is much as predicted by calculation of diffraction over a spherical earth.

---

* Strictly applicable only if the receiving point is not near the horizon.

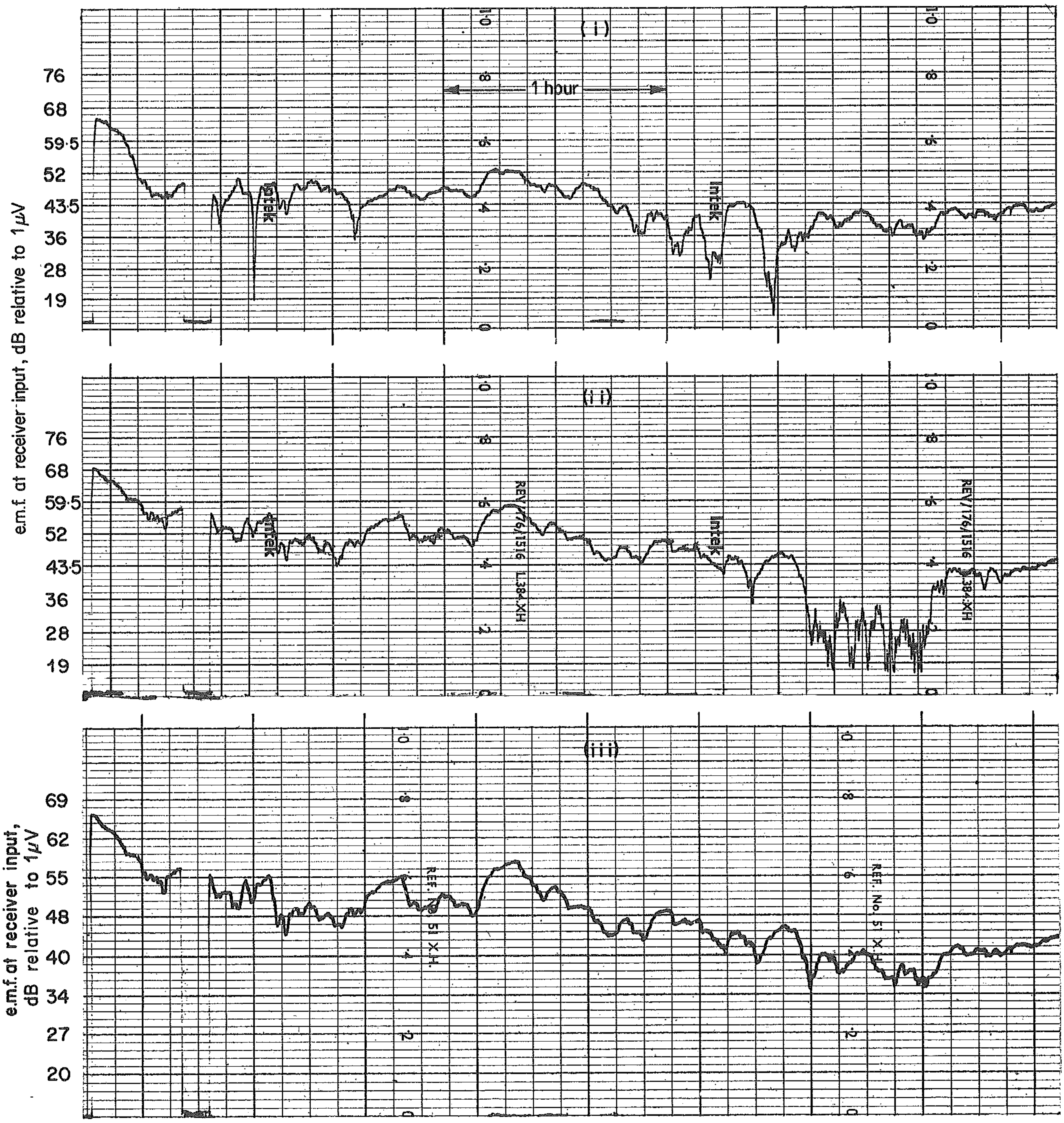
* Concurrent measurements at the two aerial heights were only made during the first part of this measurement programme.

** Termed effective height gain since this value is derived from comparison of the individual field strength distributions at the two receiving aerial heights, rather than as an analysis of the time distribution of instantaneous height gains.

The magnitudes of these effective height gains do not vary greatly over a considerable range of time percentage, but as expected, reduce to zero for the very low time percentage values corresponding to exceptionally abnormal propagation conditions.

The two receiving aerials fed separate receivers, but the facility existed for continuously recording the higher of the two individual receiver outputs thereby enabling an estimate to be made of the benefit to be derived from the use of space diversity reception, care being taken to ensure that the characteristics of the two receivers were substantially the same.

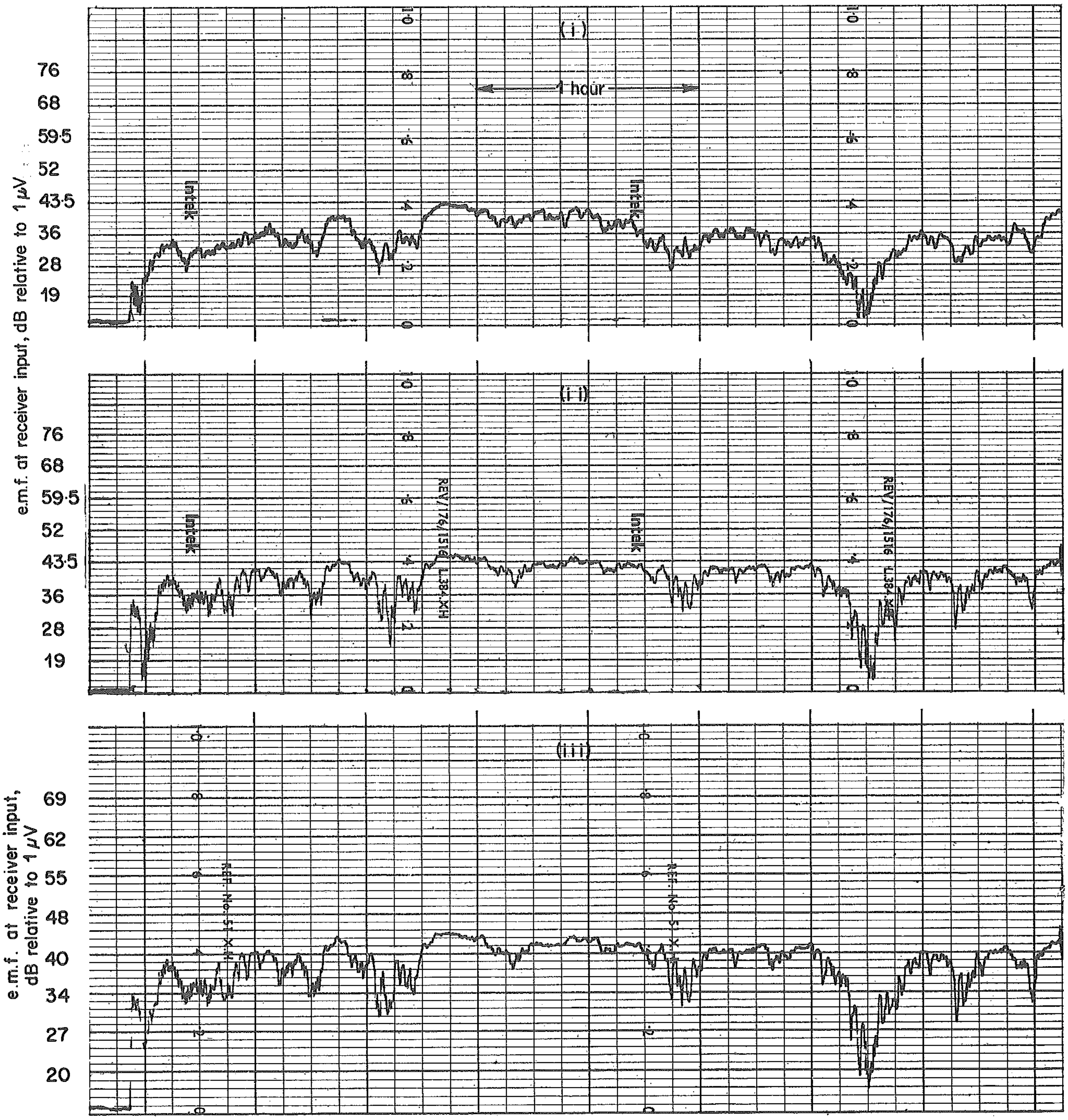
The advantage of diversity reception, expressed in terms of the relative field strength time percentage distri-



*(a)*

*Fig. 5(a) - Reception of Rowridge at Alderney*

(i) Receiving aerial at 90 m a.m.s.l. (ii) Receiving aerial at 69 m a.m.s.l. (iii) Diversity reception bution was negligible for time percentages less than 99%. Typically, monthly analyses showed the level exceeded for 99·9% of the time using the upper aerial alone to be exceeded for 99·95% of the time with height diversity. Representative examples showing occasions on which benefit is, and is not, derived from the use of such diversity are shown in Fig. 5(*a*) and Fig. 5(*b*) respectively. It should however be noted that the vertical separation between aerials was only about 40λ, which is somewhat less than that found necessary to provide useful improvements in other tests.[13] It is anticipated that further diversity reception experiments will be carried out at Alderney using greater spacings between aerials.



(*b*)

*Fig. 5(b) - Reception of Rowridge at Alderney*

(i) Receiving aerial at 90 m a.m.s.l. (ii) Receiving aerial at 69 m a.m.s.l. (iii) Diversity reception

*TABLE 7*

*Measured Field Strengths for Actual Radiated Powers of Broadcast Service Transmitters*

| a) Reception at Alderney* | Tx.(vision) e.r.p. towards Rx. site dB rel. 1 kW | Field Strength exceeded for specified time percentage. | | | |
|---|---|---|---|---|---|
| | | 50% | 90% | 99% | 99·9% |
| Transmitter 1. Rowridge | +16 | 63·5 | 58·5 | 51·5 | 40·5 |
| 2. Stockland Hill | +23† | 69·5 | 62·5 | 57·5 | 47·5 |
| 3. Portland | +17 | 67·0 | 61·5 | 58·5 | 52·0 |
| b) Reception at Torteval | | | | | |
| Transmitter 1. Rowridge | +16 | 35·5 | below receiver noise level | | |
| 2. Caradon Hill | +26 | 53·0 | 43·0 | below receiver noise level. | |

* Receiving aerial 90 m a.m.s.l.

† e.r.p. on Channel 26 (BBC-2)

## 7. Alternative possibilities for u.h.f. programme feed to the Channel Islands

The most appropriate transmitting source for providing a feed to the Channel Islands depends to some extent upon the preferred programme and upon the relative susceptibility to co-channel interference of the various available signals, Neither of these aspects is of relevance to this report, but since the preferred source is likely to be determined primarily by the need to provide adequate signal-to-noise ratio, it is of interest to compare the measurements obtained in terms of the actual or proposed transmitter radiated powers. These are shown in Table 7. In this table the assumed effective radiated power of the Portland transmitter is somewhat conjectural, but is considered to be the maximum realistic value. There is in fact no requirement for a station at this site unless required to provide a source of programme feed to the Channel Islands. Note also that although no measurements were made of transmissions from Caradon Hill at Alderney, or of Stockland Hill at Torteval, the path lengths are longer than Caradon Hill-Torteval and Stockland Hill-Alderney respectively, and thus must result in lower received field strengths.

From Table 7 it may be seen that the highest field strength values are of Stockland Hill and Portland received at Alderney. These are very similar, the higher power of the Stockland Hill transmitter compensating for the greater path length and trans-horizon distance for all time-percentages less than about 98%. Subsequent to the termination of the measurement programme detailed in this report u.h.f. television broadcast transmitters at Stockland Hill have been commissioned and a further series of measurements on Channel 26 are now in progress at Alderney. The results of the first 2 months of recording have tended to confirm the field strength distribution of Table 7, except that the median (50% time) value appears to be several decibels lower. At this early stage of the measurement programme it is not possible to confirm that this median value is representative of a longer term.

## 8. Discussion

This report summarises the results of a series of long term propagation experiments carried out over a number of paths crossing the English Channel involving path lengths ranging from 95 km to 174 km in length. These results are compared to predicted values obtained using various recognised calculation methods. It may be concluded that:

(i) Reasonable agreement is obtained for 50% time values by using the Atlases of Propagation curves (see Table 4) provided the transhorizon distance does not exceed 20% of the total path length. A better correlation would be achieved if the diffraction calculation were to be based on an assumed earth curvature factor somewhat greater than $^4/_3$.

(ii) Predicted field strengths using the curves of CCIR Rec. 370-1 agree well with the measured values for 1%, 5%, 10% times after appropriately corrected for horizon distance and open locations. Measured values tend to be somewhat higher than predicted for 50% time.

(iii) Comparison of the measurements and predictions using Method A of CCIR Report 425 emphasises a deficiency of this method over this particular distance range, in that the highest predicted field is that corresponding to the free space value. In this range of distance this prediction method tends to under-estimate the field strength exceeded for 1% time and overestimate that for 50% time. It should be emphasised that this method was based on very limited data available over such paths and it is to be expected that the more comprehensive prediction procedures presently being developed within Research Department will substantially reduce these discrepancies.

Although simultaneous measurements at the receiving aerial heights showed only a very small advantage to be gained from space diversity at a separation distance of about 40λ, the measurements did not enable any estimates to be made of the subjective improvement obtainable from diversity reception in terms of reduction of differential phase and amplitude distortions. Comparable experiments from the mainland of Italy to Sardinia[13] have shown that space diversity may significantly reduce distortion of television colour transmissions during periods of deep fading.

## 9. Acknowledgements

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(ii) The Post Office and the States of Guernsey Telephone Department for facilities at the Post Office Receiving Station, Alderney, particular thanks being due to Mr. K. Thompson of the States Telephone Department.

(iii) The Engineer-in-Charge of the I.T.A. transmitting station, Stockland Hill.

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## APPENDIX

(i) In addition to the measurements detailed in the text of this report an earlier series of measurements were carried out over a transmission path from the BBC transmitting station at North Hessary Tor (Devon) to Torteval, Guernsey. The transmission path length was 157 km of which only 119 km were oversea, and therefore this path should be considered as a mixed land/sea path.

Furthermore the range of the receiver did not permit the higher field strength levels exceeded for small percentages of the time to be established. The results of these measurements are however detailed here for completeness and because they include space diversity tests similar to these discussed in Section 6.

(ii) **Transmitting site and path details**

The transmission path is shown in Fig. 1, transmitter details being as follows:

| Station | Site height a.m.s.l. (m) | Aerial Height a.g.l. (m) | Latitude | Longitude | Transmission Frequency MHz |
|---|---|---|---|---|---|
| North Hessary Tor | 509 | 209 | 50°32′59″N | 04°00′26″W | 759·25 MHz |

The test transmission was of low power and square wave modulated at 1000 Hz to a depth of 100%. At the Torteval receiving site a single receiver was switched alternately between two receiving aerials and corresponding output pen recorders, switching being at a sufficiently high rate to enable two continuous chart recordings to be obtained corresponding to the inputs from the two receiving aerials. A third recording enabled the diversity improvement to be obtained.

(iii) **Results**

The measurements were divided into three consecutive periods each of about three months duration. For the first and third periods vertical height diversity was employed with the receiving aerials at approximately 11 m and 30 m above ground level. During the second period the two receiving aerials were both at 11 m above ground level and spaced by a horizontal distance (perpendicular to the propagation path) of 37 m. The following Table summarises the results of these measurements:—

| Period | Duration | Receiving Aerial | Field strength exceeded for specified time percentage dB (μV/m) for 1 kW e.r.p. | | | |
|---|---|---|---|---|---|---|
| | | | 50% | 90% | 99% | 99·9% |
| 1 | December 1962 to March 1963 | 30 m a.g.l. | 44 | 41·5 | 37 | 31 |
| | | 11 m a.g.l. | 42 | 39 | 34·5 | 26·5 |
| | | 'Diversity' | 44 | 41·5 | 37·5 | 31 |
| 2 | March 1963 to June 1963 | 11 m a.g.l.* | 48 | 38·5 | 29·5 | 23 |
| | | 'Diversity' | 48 | 39 | 30 | 25 |
| 3 | June 1963 to Sept. 1963 | 30 m a.g.l. | 46·5 | 40·5 | 33·5 | 22·5 |
| | | 11 m a.g.l. | 44·5 | 38 | 31 | 21 |
| | | 'Diversity' | 47 | 40·5 | 35 | 27 |

* Mean value of individual distributions for the two receiving aerials spaced 37 m

### (iv) Comments

It may be noted that the median (50%) field strength value for the measurements at 11 m a.g.l. shows an overall variation of 6 dB for the three different periods, emphasising the importance of carrying out measurements over an extended period. The overall median field strength at this aerial height for the full nine-month extent of the experiment is 45 dB ($\mu$V/m) for 1 kW e.r.p. which is in close agreement with the value predicted from the CCIR or Japanese Atlases of propagation curves. From the comparisons previously discussed in Section 5.2, this good agreement is to be expected, since although the transmitting site is well inland the transmitting terminal height is sufficiently great to ensure negligible diffraction losses due to this terrain, and the distance between horizons for 4/3 earth radius is approximately 10 km. As for most of the other paths the prediction method of CCIR Rec. 370-1 (see Section 5.3) underestimates the median field strength, and that of CCIR Report 425 (see Section 5.4) overestimates it.

The statistical analysis shows that very little advantage was derived from diversity reception for the first two periods corresponding roughly to winter and spring. In the final period, corresponding to the summer months, a useful reduction in the depth of fading was shown, the field strengths exceeded for 99% and 99·9% of the time at the upper aerial being exceeded for 99·5% and 99·98% of the time, respectively with diversity reception.

SMW/EP

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